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Impact of Fixed Orthodontic Wire Materials on Saliva pH Levels and Flow Rates: A Clinical Investigation

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Abstract

Objective(s): This study aimed to investigate the changes in salivary pH and flow rates during fixed orthodontic treatment with nickel-titanium (Ni-Ti) and stainless steel (SS) wires. **Methods:** A longitudinal clinical investigation was conducted among 43 participants undergoing fixed orthodontic treatment. Salivary pH levels and flow rates were measured at three time points: before treatment (T1), one month after placement of Ni-Ti 0.016 wires (T2), and one month after placement of SS 0.016 wires (T3). Repeated-measures ANOVA was performed to analyze trends over time, and pairwise comparisons with Bonferroni adjustment were used to identify significant differences between the time points. Statistical analysis was conducted at a significance level of 0.05. **Results:** A significant progressive decline in salivary pH levels was observed, with mean values decreasing from 6.85 at T1 to 6.71 at T2 and 6.68 at T3 ($p < 0.001$). Both linear ($F = 128.360$, $p < 0.001$) and quadratic trends ($F = 19.680$, $p < 0.001$) were evident. Saliva flow rates showed a slight but significant increase after wire placement (T2: 0.375 ml; T3: 0.374 ml) compared to baseline (T1: 0.358 ml), stabilizing thereafter ($p = 0.003$). Pairwise comparisons revealed greater pH declines after SS wire placement compared to Ni-Ti wires ($p = 0.002$). **Conclusions:** Fixed orthodontic treatment significantly affects salivary pH levels and flow rates, with SS wires exerting a greater impact on oral acidity. These results highlight the need for preventive strategies to mitigate potential adverse effects on oral health during orthodontic treatment.

Keywords: Fixed Orthodontic Treatment; Orthodontic Wires; Saliva PH Levels; Saliva Flow Rates; Treatment Outcomes

Introduction

Fixed orthodontic treatment (FOT) is crucial for correcting dental irregularities and achieving optimal oral health.[1] Orthodontic wires, made from materials like Nickel-Titanium (Ni-Ti) and stainless steel, play a significant role in aligning teeth and ensuring proper bite. The selection of wire materials is critical, as it affects treatment outcomes.[2] This introduction highlights the need to examine the impact of wire materials on saliva amount and pH levels. Saliva is essential for maintaining oral health by buffering acids, cleansing the oral cavity, and facilitating enamel remineralization.[3] Changes in saliva amount and pH levels during fixed orthodontic treatment can lead to complications such as enamel demineralization, dental caries, and soft tissue irritation.[4] Understanding how different wire materials interact with saliva and influence pH levels is vital for optimizing treatment outcomes, reducing adverse effects, and enhancing patient comfort.[5]
Orthodontic treatment with fixed appliances introduces significant changes to the oral environment, particularly in salivary properties such as pH levels and flow rates.[6] Saliva plays a critical role in maintaining oral health by lubricating tissues, facilitating essential functions like mastication and speech, and providing a natural defense against microbial attacks. However, the placement of orthodontic brackets and wires can disrupt this balance, leading to potential complications such as enamel demineralization and increased microbial activity.[7, 8]
The interaction between orthodontic materials and saliva is multifaceted. Various studies have highlighted that different materials, such as metal and ceramic brackets or wires, can influence salivary pH and flow rates due to mechanical irritation, ion release, or changes in the oral microflora.[9] For instance, metal-based appliances are often associated with a more pronounced decrease in salivary pH compared to ceramic or clear aligners. Additionally, stimulated salivary flow rates tend to increase during treatment due to physiological responses to the appliances, while unstimulated flow rates may exhibit variable patterns.[10]
Understanding these changes is essential for improving treatment outcomes and minimizing risks such as caries or corrosion of orthodontic components. This clinical investigation aimed to explore the impact of orthodontic wire and bracket materials on salivary pH levels and flow rates during fixed orthodontic treatment, providing insights into the dynamic interplay between orthodontic appliances and the oral environment.[11, 12]

The purpose of the study was to investigate and determine how the choice of orthodontic wire material (specifically Ni-Ti and stainless steel) affects the saliva flow rates and pH levels in patients undergoing fixed orthodontic treatment.

Methods

Sample and study plan

This study was a semi-experimental longitudinal clinical research targeting patients receiving fixed orthodontic treatment with two types of wires: Ni-Ti and stainless-steel. A total of 43 patients were randomly selected for the study. Ethical approval was obtained from the Research Ethics Committees of Ilam University of Medical Sciences (Approval ID: IR.MEDILAM.REC.1402.030). Written informed consent was obtained from all participants as a mandatory prerequisite.

All selected patients underwent the same procedure using 0.022-inch straight wire brackets. Saliva sampling was carried out in three steps (T1, T2, and T3) (Figure 1).

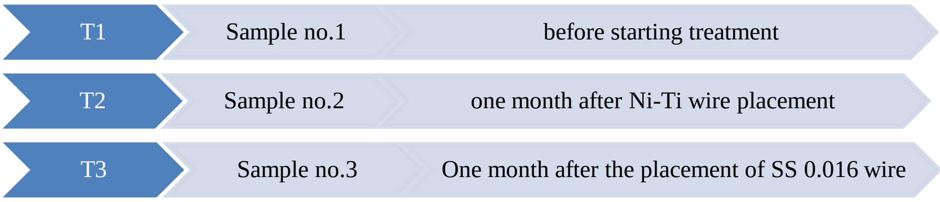

Figure 1: Study plan for saliva sampling

Saliva sampling

The initial saliva sample was collected from patients before the commencement of treatment (T1). In the first phase, the treatment group received fixed orthodontic treatment using a 0.016-inch Ni-Ti wire. After one month (following the placement of the Ni-Ti wire), a second saliva sample (T2) was obtained to assess pH and unstimulated salivary flow. Subsequently, after six months, the Ni-Ti wire was removed. Following a two-day interval without the wire and ensuring hygienic conditions, the patients were fitted with a 0.016-inch stainless-steel wire. One month after the placement of the stainless-steel wire, the third sample (T3) was collected from the patients. pH and salivary flow rate were measured immediately after sample collection.

The conditions for saliva sampling at all time points were as follows: patients were instructed to sit calmly with their mouths open, heads tilted, and allow all resting saliva to flow into a graduated mouthpiece for five minutes. Saliva samples were obtained between 9:00 AM and 12:00 PM, at least two hours post-meal and oral hygiene practices (brushing and flossing) to reduce daily variations in saliva composition. Prior to the placement of the orthodontic appliance, the patients underwent oral prophylaxis by an orthodontist. Oral and dental hygiene instructions were given to the patients in written and verbal forms after the fixed orthodontic appliance placement.

Statistical analysis

Statistical analysis was performed using SPSS 26 software. Repeated-measures ANOVA was employed to evaluate changes in salivary pH levels and flow rates across three time points: before treatment (T1), one month after the placement of Ni-Ti 0.016 wires (T2), and one month after the placement of stainless steel 0.016 wires (T3). Linear and quadratic trends were assessed to identify patterns of change over time, while pairwise comparisons with Bonferroni adjustment were conducted to determine significant differences between specific time points. The level of statistical significance was set at $p < 0.05$, ensuring robust analysis of within-subject variations while controlling for type I errors due to multiple comparisons.

Results

In this study, 43 patients were enrolled, with 62% of them being women, and the overall mean age ± SD was 22 ± 7.3. The mean pH levels of saliva before the onset of treatment (T1) were 6.85±0.169. One month after starting orthodontics with Ni-Ti (T2), the pH levels reached 6.70±0.155, and one month after starting orthodontics with Stainless-Steel (T3), it decreased to 6.67±0.134. The mean salivary flow rates were 0.358±0.065 at T1, 0.375±0.066 at T2, and 0.374±0.068 at T3 (Table 1) (Figures 2 and 3).

Repeated-measures ANOVA revealed significant linear and quadratic trends in pH levels across the three time points. The linear trend accounted for a significant proportion of variance ($F = 128.360$, $p < 0.001$, partial $\eta^2 = 0.753$), as did the quadratic trend ($F = 19.680$, $p < 0.001$, partial $\eta^2 = 0.319$). The linear and quadratic trends confirmed a steady decline in pH levels, with some variation in the rate of change, likely influenced by the type of orthodontic wire used. For the salivary flow, a significant linear trend was observed ($F = 9.847$, $p = 0.003$, partial $\eta^2 = 0.190$), while the quadratic trend was not significant ($F = 2.272$, $p = 0.139$, partial $\eta^2 = 0.051$). Salivary flow rates increased slightly over time, but this change was relatively stable and less pronounced compared to the changes in pH levels (Table 2).

Table 1- Mean±SD of salivary pH levels and flow rates during fixed orthodontic treatment

		N	Mean	Std. Deviation
pH levels	T1	43	6.85	0.169
	T2	43	6.70	0.155
	T3	43	6.67	0.134
	Total	129	6.74	0.171
flow rates	T1	43	0.358	0.065
	T2	43	0.375	0.066
	T3	43	0.374	0.072
	Total	129	0.369	0.068

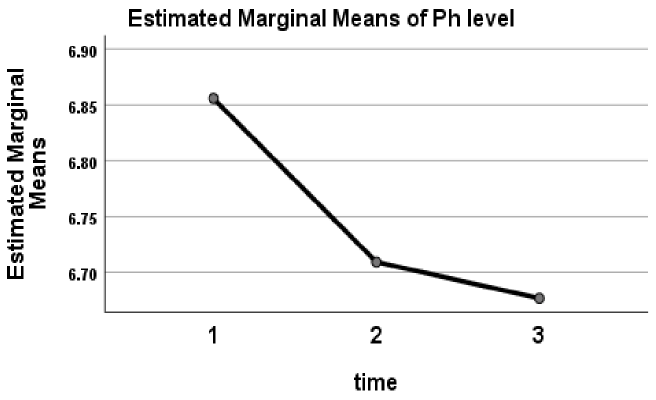

Figure 2: The mean salivary pH levels in three time points

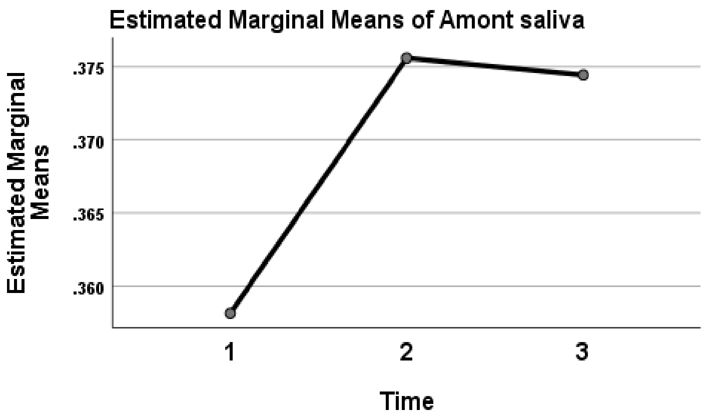

Figure 3: The mean salivary flow in three time points

Table 2- Multiple comparisons of salivary pH levels and flow rates in different time points

Source	Measure	factor1	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	pH level	Linear	0.689	1	0.689	128.360	<0.001	0.753
		Quadratic	0.093	1	0.093	19.680	<0.001	0.319
	salivary flow	Linear	0.006	1	0.006	9.847	0.003	0.190
		Quadratic	0.002	1	0.002	2.272	0.139	0.051

Pairwise comparisons with Bonferroni adjustment showed significant differences in pH levels between T1 and T2 (mean difference = 0.147, p < 0.001), T1 and T3 (mean difference = 0.179, p < 0.001), and T2 and T3 (mean difference = 0.033, p = 0.075). For the salivary flow, significant differences were observed between T1 and T2 (mean difference = -0.017, p = 0.029), T1 and T3 (mean difference = -0.016, p = 0.009), and T2 and T3 (mean difference = 0.001, p = 1.000) (Table 3).

Table 3- Pairwise comparisons of salivary pH levels and flow rates in different time points

Measure	(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[b]
Ph level	T1	T2	0.147*	0.016	<0.001
		T3	0.179*	0.016	<0.001
	T2	T1	-0.147*	0.016	<0.001
		T3	0.033	0.014	0.075
	T3	T1	-0.179*	0.016	<0.001
		T2	-0.033	0.014	0.075
Amont saliva	T1	T2	-0.017*	0.006	0.029
		T3	-0.016*	0.005	0.009
	T2	T1	0.017*	0.006	0.029
		T3	0.001	0.007	1.000
	T3	T1	0.016*	0.005	0.009
		T2	-0.001	0.007	1.000

Discussion

The findings of the present study provided valuable insights into the impact of orthodontic wire materials and treatment progression on salivary pH levels and flow rates. These results contribute to a deeper understanding of the physiological changes that occur during fixed orthodontic treatment and their potential implications for oral health.

In the present study, a significant decrease in salivary pH levels was observed over the course of orthodontic treatment. This finding aligned with previous studies by Al-Musallam et al. [13] and S. Arab et al. [14], who reported similar trends of declining pH levels during fixed orthodontic therapy. The comparison between Ni-Ti and stainless steel wires revealed a more pronounced decline in pH levels after the placement of stainless steel wires, corroborating findings from Kouvelis et al. [15] and Alam MK et al. [16]. This material-specific effect may be attributed to differences in surface characteristics, frictional forces, and microbial adhesion associated with these wires. Stainless steel wires, being less biocompatible and more prone to plaque retention due to higher surface roughness and friction, may create a more favorable environment for acidogenic bacteria. In contrast, Ni-Ti wires, with their smoother surfaces and lower friction, may exert a lesser impact on oral pH. The initial drop in pH following the placement of Ni-Ti wires and the subsequent greater decline after stainless steel wire placement suggest that the material properties of orthodontic wires may influence oral acidity. These findings emphasize the importance of selecting appropriate wire materials based on individual patient needs and oral health status. The progressive acidification of saliva could predispose patients to enamel demineralization and caries, highlighting the need for preventive measures such as fluoride application and dietary counseling during orthodontic treatment.

The present study also demonstrated a slight but significant increase in saliva flow rates immediately after the placement of orthodontic wires, which stabilized thereafter. These findings were consistent with prior research by Kılınç et al. [3] and Upadhyay et al. [4], who also observed an initial increase in salivary secretion followed by stabilization. The transient rise in saliva flow rates may be attributed to the body's adaptive response to the presence of foreign objects (orthodontic appliances) in the oral cavity. Increased salivary flow can enhance the buffering capacity of saliva, potentially mitigating the effects of decreased pH levels. However, the stabilization of flow rates in later stages suggests that this compensatory mechanism may not persist indefinitely, underscoring the importance of maintaining optimal oral hygiene to counteract the acidic environment.

The observed changes in salivary pH and flow rates have significant clinical implications for orthodontic practice. The progressive decline in pH levels underscores the risk of enamel demineralization and dental caries during orthodontic treatment, particularly with the use of SS wires. Clinicians should consider implementing preventive strategies, such as regular fluoride varnish applications, dietary advice to reduce sugar intake, and meticulous oral hygiene instructions, to mitigate these risks. Additionally, monitoring salivary parameters during treatment could serve as a useful tool for identifying patients at higher risk of developing complications. The initial increase in saliva flow rates, although beneficial, may not be sufficient to counteract the long-term effects of decreased pH, necessitating proactive management.

The results of this study were broadly consistent with existing literature, reinforcing the reliability of the findings. For instance, Alshahrani et al. [17] and Abrol et al. [18] also reported stabilization of saliva flow rates after an initial increase, supporting the current observations. Similarly, the greater impact of stainless steel wires on pH levels has been documented in multiple studies [15, 16], further validating the material-specific effects observed in this investigation. However, while previous studies have explored similar parameters, the current study provides a comprehensive analysis by examining both pH levels and saliva flow rates across different wire materials, offering a more holistic understanding of the oral environment during orthodontic treatment.

Despite the robust methodology and significant findings, this study had certain limitations. A critical limitation of this study was the difficulty in isolating the effects of orthodontic wires from those of stainless steel brackets. Since all participants were treated using stainless steel brackets, the observed changes in salivary pH and flow rates at the start of treatment might have been influenced not only by Ni-Ti wires but also by the stainless steel brackets themselves. stainless steel brackets, due to their surface roughness and tendency to accumulate plaque, may contribute to increased bacterial colonization and acid production. Prior research suggests that stainless steel brackets can alter microbial adhesion, exacerbating reductions in pH levels independent of wire material.[15] This overlap in material effects suggests that future studies should consider comparing different bracket materials or controlling for their influence.

Furthermore, the sample size, although adequate, was relatively small. The study focused exclusively on short-term changes in salivary parameters. Future research should include larger cohorts and longer follow-up periods to assess the long-term effects of orthodontic treatment on oral health. Additionally, incorporating other variables such as microbial counts, dietary habits, and patient compliance with oral hygiene practices could provide a more comprehensive picture of the factors influencing salivary pH and flow rates. Investigating the efficacy of various preventive interventions in mitigating the adverse effects of orthodontic treatment would also be valuable for future research.

Conclusion

In conclusion, the present study highlights the significant impact of orthodontic wire materials and treatment progression on salivary pH levels and flow rates. The progressive decline in pH levels, particularly after the placement of stainless steel wires, underscores the need for preventive measures to protect oral health during orthodontic treatment. The initial increase in saliva flow rates, while beneficial, stabilizes over time, emphasizing the importance of proactive caries prevention strategies. These findings contribute to the growing body of evidence on the physiological changes associated with fixed orthodontic treatment and provide valuable insights for optimizing patient care.

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Author Contributions: F.F.: designed the study, literature review, preparation, and editing of the manuscript. H.S.: participated in the design of the study, data collection, preparation, and editing. M.E., and K.S.: participated in the study design, data collection, preparation, and editing of the manuscript. All authors (F.F, H.S, and M.E, and K.S) reviewed the preliminary and final analyses and the drafts. Finally, all authors read and approved the manuscript.

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Using AI: No generative AI was used in the preparation of this manuscript.

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